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An emitter manufacturing method comprises the step of forming on a glass substrate (201) a CNT film (212) containing carbon nano-tubes (CNTs) (212a) and constituting an emitter electrode, forming a gate electrode (216) above the CNT film (212) with an insulation film (213) interposed in between, forming gate openings in the gate electrode (216) and the insulation film (213), and orientating the CNTs (212a) upright in the gate opening. The upright orientation causes a uniform and stable emission current to provide good emission characteristics.

TRANSLATION

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(54) Title of Invention:
CNT Film and Field-Emission Cold Cathode Comprising the Same

CLAIMS

1. A CNT film characterized by the fact that it is a CNT film containing carbon nanotubes (CNT) and particulate impurities, and the area ratio of CNT to particulate impurities in the cross section and surface structure is set to the range of 0.5:99.5 ~ 40:60.

2. The CNT film as described in Claim 1 characterized by the fact that the aforementioned particulate impurities comprise the impurities obtained together with the said CNT when the aforementioned CNT is produced.

3. The CNT film as described in Claim 1 or 2 characterized by the fact that the aforementioned particulate impurities function as a binder to fill the gap between CNTs, and a binder separate from the said binder is further added.

4. The CNT film as described in Claim 3 characterized by the fact that the aforementioned separate binder comprises an organic substance.

5. The CNT film as described in Claim 4 characterized by the fact that the aforementioned organic substance is comprised of a material containing at least one among acrylic, nitrocellulose and polyimide resins.

6. The CNT film as described in Claim 1 ~ 5 characterized by the fact that the aforementioned particulate impurities and CNT occupy 70 % or higher of the aforementioned CNT film.

7. The CNT film as described in any of Claims 3 ~ 6 characterized by the fact that the aforementioned CNT film consists of two layers or more of laminated films that are laminated successively, and the content percentages of CNT, particulate impurities and the separate binder in each layer of the said laminated film are set separately.

8. The CNT film as described in Claim 7 characterized by the fact that, in the aforementioned CNT, particulate impurities and separate binder, the higher the layer, the higher the content percentage of CNT is, and the lower the layer, the higher the content percentage of the aforementioned particulate impurities and separate binder is.

9. The CNT film as described in Claim 8 characterized by the fact that the content percentage of CNT in the uppermost layer is 80 ~ 90 %, the content percentage of those other than CNT in the layer below the uppermost layer is 70 ~ 80%, and the content percentage of the aforementioned separate binder in the lowest layer is 60 ~ 70 %.

10. A field-emission cold cathode characterized by the fact that the CNT film as described in any of Claims 1 ~ 9 is employed.

11. A production method for a CNT film characterized by the fact that it is a production method for the CNT film as described in any of Claims 1 ~ 9, and the binder consisting of the aforementioned particulate impurities and/or the aforementioned separate binder is comprised of a material having a faster etching rate than that of CNT, and the aforementioned CNT film is subjected to patterning.

12. The production method for the CNT film as described in Claim 11 characterized by the fact that the aforementioned binder and/or the separate binder is also allowed to remain together with CNT in the region of the CNT film allowed to remain in the aforementioned CNT patterning step.

13. The CNT film production method as described in Claim 11 or 12 characterized by the fact that the CNT and particulate impurities obtained simultaneously in the same step are used.

14. The CNT film production method as described in claim 11 or 12 characterized by the fact that the CNT and particulate impurities obtained from the steps different from each other are used.

15. A production method for a CNT film characterized by the fact that it is a production method in which a pair of carbon rods which face each other inside a chamber are used to carry out arc discharge, CNT and particulate impurities are allowed to accumulate on the top, side and bottom inside the aforementioned chamber, and the said accumulation is used to produce the CNT film; and that the top accumulation and side accumulation which accumulate respectively on the top and the side inside the aforementioned chamber are recovered, both of the aforementioned top accumulation and side accumulation that are recovered are mixed at a prescribed ratio to form a mixed material, and the aforementioned particulate impurities in the said mixed material are used as the material to fill the gap between CNTs in the said mixed material.

16. The production method for the CNT film as described in Claim 15 characterized by the fact that the aforementioned side accumulation and the aforementioned top accumulation are used to adjust the contents of the CNT film and particulate impurities so that the area ratio of CNT to particulate impurities in the cross section and surface structure satisfies the range of 0.5 : 99.5 ~ 40 : 60.

17. A CNT film production method for CNT film characterized by the fact it is a method to produce the CNT film as described in Claim 1 ~ 9, and has a step to orient the CNT film surface upright.

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18. A field-emission cold cathode characterized by the fact that the CNT film produced by the CNT film production method as described in any of Claims 11 ~ 17 is employed.

19. The electron-emission cold cathode as described in Claim 18 characterized by the fact that the aforementioned CNT film forms the electron-emission surface containing the aforementioned CNT and particulate impurities, and the said electron-emission surface does not contain particulate impurities of over 500 nm in particle size.

20. A field-emission image indicator characterized by the fact that the electron-emission cold cathode as described in Claim 19 is used.

21. An emitter production method characterized by the fact that a CNT film containing multiple carbon nano-tubes (CNT) and constituting an emitter is formed on a substrate, and the aforementioned CNT on the CNT film surface is oriented upright.

22. The production method for the emitter as described in Claim 21 characterized by the fact that, in the aforementioned step of upright orientation of CNT, an adhesive sheet is adhered to the aforementioned CNT film followed by orienting the CNT upright by peeling off the said adhesive sheet.

23. The emitter production method as described in Claim 21 characterized by the fact that it comprises a step to form an electrode on the aforementioned CNT film with an insulation film interposed in between, and a step to form multiple openings in the aforementioned electrode and insulation film prior to the aforementioned upright orientation step of the CNT; and, in the aforementioned CNT upright orientation step, the CNT inside the aforementioned opening is oriented upright.

24. The emitter production method as described in Claim 23 characterized by the fact that the aforementioned upright orientation step comprises a step in which an adhesive sheet is allowed to enter inside the aforementioned opening followed by peeling off the said adhesive sheet.

25. The emitter production method as described in Claim 23 characterized by the fact that it has a step to orient upright the CNT on the aforementioned CNT film surface and also to form on the said CNT film a particulate-containing cover film prior to the aforementioned step to form an insulation film and an electrode; and the aforementioned upright orientation step comprises a step to allow an adhesive sheet to enter inside the aforementioned opening followed by peeling off the said adhesive sheet and removing at least part of the aforementioned cover film.

26. The emitter production method as described in Claim 24 or 25 characterized by the fact that the aforementioned step of upright orientation by the use of an adhesive sheet is carried out under reduced pressure.

27. The emitter production process as described in any of Claims 24 ~ 26 characterized by the fact that the aforementioned adhesive sheet has permeability.

28. The emitter production method as described in any of Claims 24 ~ 27 characterized by the fact that a tacky convex that enters the aforementioned multiple openings is formed on the aforementioned adhesive sheet surface.

29. The emitter production method as described in Claim 28 characterized by the fact that the aforementioned tacky convex is arranged to be smaller than the aforementioned multiple openings.

30. The emitter production method as described in any of Claims 24 ~ 29 characterized by the fact that the adhesion strength of the aforementioned adhesive sheet is over 0.002 N/mm and less than 0.2 N/mm.

31. An emitter production method characterized by the fact that a CNT film that constitutes an emitter and comprises multiple carbon nano-tubes (CNT) is formed on a substrate; the CNT of the aforementioned CNT film is oriented upright and a metal protective film is formed on the said upright-oriented CNT film; and the whole substrate containing the aforementioned metal protective film is immersed in an etching solution to remove the aforementioned metal protective film.

32. The emitter production method as described in Claim 31 characterized by the fact that it comprises a step to form an electrode on the aforementioned metal protective film with an insulation film interposed in between, and a step to form multiple openings in the aforementioned electrode and insulation film prior to a step to remove the aforementioned metal protective film; and, in the aforementioned step to remove the aforementioned metal protective film, the aforementioned metal protective film inside the opening is removed by etching.

33. The emitter production method as described in Claim 32 characterized by the fact that following the aforementioned step to remove a metal protective film it comprises a step to substitute water for the aforementioned etching solution as the aforementioned CNT film exposed inside the aforementioned opening is maintained below the liquid surface; and a step to sublime the aforementioned water after freezing and dry the upright-oriented CNT in the aforementioned CNT film.

34. The emitter production method as described in Claim 32 characterized by the fact that following the aforementioned step to remove a metal protective film it comprises a step to substitute a supercritical fluid for the aforementioned etching solution as the aforementioned CNT film exposed inside the aforementioned opening is maintained below the liquid surface; and a step to remove the aforementioned supercritical fluid by converting it to the supercritical state and dry the aforementioned CNT film.

35. The emitter production method as described in Claim 34 characterized by the fact that the aforementioned supercritical fluid contains at least one among liquid CO_2, N_2, N_2O, Xenon and SF_6.

36. The emitter production method as described in Claim 32 characterized by the fact that following the aforementioned step to remove a metal protective film a solution having surface tension lower than that of the aforementioned etching solution is substituted for the said etching solution as the aforementioned CNT film exposed inside the aforementioned opening is maintained below the liquid surface, and the aforementioned CNT film is dried thereafter.

37. The emitter production method as described in any of Claims 33, 34 and 36 characterized by the fact that the aforementioned drying step is carried out under a constant pressure and/or at a constant temperature.

38. An emitter production method characterized by the fact that, in a production method to produce an electrode with a CNT film comprising multiple carbon nano-tubes (CNT),

after the aforementioned CNT film is wetted with a prescribed solution, and the CNT is allowed to fall sideways and arranged, a specified film is formed on the aforementioned CNT film.

39. A field-emission cold cathode characterized by the fact that it has an emitter produced by the emitter production method as described in any of Claims 20 ~ 38.

40. A plane image indicator characterized by having the field-emission cold cathode as described in Claim 39.

41. A plane image indicator characterized by the fact that, in a plane image indicator in which the area of one picture element is S (cm^2), the number density of the upright-oriented CNT is 1/S (number/cm^2) or more.

42. A field-emission cold cathode characterized by the fact that the field-emision cold cathode is equipped with a CNT layer (, which is formed on a substrate, comprises multiple carbon nano-tubes (CNT) and constitutes an emitter,) and a gate insulation layer and a gate electrode layer (each of which is formed successively on the said CNT layer, and which expose the aforementioned CNT layer surface from the through opening); it emits electrons from the aforementioned emitter surface by applying a voltage to each of the aforementioned emitter and gate electrode layer: and the aforementioned gate insulation layer is comprised of a multilayer insulation layer of more than two layers laminated successively.

43. The field-emission cold cathode as described in Claim 41 characterized by the fact that an intermediate layer is further formed between the aforementioned CNT layer and gate insulation layer.

44. The field-emission cold cathode as described in Claim 43 or 44 characterized by the fact that the aforementioned insulation layer direct above the CNT layer has a film thickness of 0.2 μ or more but 2 μm or less.

45. The field-emission cold cathode as described in any of Claims 42 ~ 44 characterized by the fact that, in the aforementioned multilayer insulation layer, the size of the aforementioned opening in at least one layer of the insulation layer is greater than the size of the aforementioned opening in the aforementioned gate electrode layer.

46. A plane image indicator characterized by the fact that it is equipped with the field-emission cold cathode as described in any of Claims 42 ~ 45.

47. A production method for a field-emission cathode characterized by the fact that a conductive layer, a CNT layer comprising multiple carbon nano-tubes (CNT), a gate insulation layer comprising a multilayer insulation layer with more than two layers laminated successively and a gate electrode layer are formed in this order on a substrate; the aforementioned gate electrode layer and gate insulation layer are removed by etching

to form an opening; and the aforementioned CNT layer surface is exposed from the said opening to form an emitter.

48. The production method for the field-cmission cold cathode as described in Claim 47 characterized by the fact that it further comprises a step to form an intermediate layer between the aforementioned CNT layer and gate insulation layer.

49. The production method for the field-emission cold cathode as described in Claim 47 or 48 characterized by the fact that the aforementioned insulation layer directly above the CNT layer is comprised of a coated film with a thickness of 0.2 μm or more but 2 μm or less.

50. The production method for the field-emission cold cathode as described in Claim 49 characterized by the fact that the aforementioned coated film consists of 50 G (Spin on Glass).

51. The production method for the field-emission cold cathode as described in any of Claims 47 ~ 50 characterized by the fact that the opening size of at least one layer of the insulation layer in the aforementioned gate insulation layer is formed with a greater size than the opening size of the aforementioned gate electrode layer.

52. The production method for the field-emission cold cathode as described in any of Claims 47 ~ 51 characterized by the fact that it further has a step to orient upright the aforementioned CNT film.

53. A plane image indicator characterized by the fact that it is equipped with a field-emission cold cathode formed by the production method for the field-emission cold cathode as described in any of Claims 47 ~ 52.

Translation: I&CT
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